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ARRAY ELEMENTS FOR A DBS FLAT-PLATE ANTENNA

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Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

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Summary

The introduction of a direct broadcast by satellite (DBS) television service requires suitable receiving antennas to be available. An alternative to the parabolic dish antenna is a flat-plate antenna. The overall design of a circularly-polarised flat-plate antenna which can be mounted flat on the wall of a building has been considered in a companion Report. In this Report various types of elements are investigated and their advantages and disadvanges discussed. The most suitable element for use in a flat-plate array is identified as a linearly-polarised folded-dipole element; its performance is reported here. Linearly-polarised elements are found to perform better than circularly-polarised elements and could be used with a polarisation converter to receive the circularly-polarised radiation that would be transmitted by DBS.

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ARRAY ELEMENTS FOR A DBS FLAT-PLATE ANTENNA

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1. INTRODUCTION

The introduction of a direct broadcast by satellite (DBS) television service requires suitable receiving antennas to be available. It was originally assumed at the World Administrative Radio Conference of 1977 (WARC-77)[1], which planned the 12 GHz band for DBS services, that a parabolic dish antenna would be used. However, this approach may be environmentally undesirable and poses significant mechanical constraints on the dish mounting assembly.

An alternative solution to the parabolic dish antenna is a flat-plate antenna. Such an antenna consists of a large number of antenna elements the outputs of which are combined together by transmission lines. The elements are all mounted in the same plane, resulting in a thin, flat structure. The phased-array principle is used to receive signals from the desired direction — which may not be, and indeed usually is not, orthogonal to the plane of the antenna. This gives a flat-plate antenna a number of potential advantages over a parabolic dish — for example it could be mounted flat and hence unobtrusively on an outside wall or roof. However, a domestic flat-plate antenna should be low-cost so that it can compete favourably with a parabolic dish. As a result low-cost materials and construction techniques should be used.

The overall design of a flat-plate antenna which can be mounted flat on the most favourable wall of a building is considered in Ref. 2. Three, somewhat interactive, requirements must be considered in designing a suitable antenna:

(a) reception of circularly-polarised signals,

(b) achievement of sufficient antenna gain and directivity,

(c) combination of the signals from each antenna element so as to receive signals from the desired direction.

This Report considers the second of these problems. The performance of various flat-plate antenna elements, both individually and in small arrays, are considered and the advantages and disadvantages of each discussed. Both linearly and circularly-polarised elements are considered as the former can be used in conjunction with a polarisation converter.

2. THE INVESTIGATION OF VARIOUS TYPES OF ANTENNA ELEMENT

The requirements for an ideal array element for use in the antenna proposed in Ref. 2 can be summarised. To allow reception of DBS signals from a satellite in the UK orbit position, the element should operate over the frequency range 11.7 GHz to 12.1 GHz, it should have a co-polar gain of around 9 dBi and a cross-polar discrimination of better than 20 dB. In the final array the mainbeam will be steered in one plane over a range of angles from 16° to 52° on only one side of broadside. The element must therefore exhibit adequate co-polar gain in these directions. To allow steering of the mainbeam of the final array, the elements must be separated by no more than 0.56 wavelengths in one plane and 0.95 wavelengths in the other; therefore the elements should be kept small. Furthermore, for accurate steering and to maintain the array gain the mutual coupling between the elements should also be kept low.

The materials and construction techniques used should be low-cost for the final array to be suitable for the domestic market. In this work printed circuit etching techniques were used which are considered to be relatively low-cost and suitable for mass production. However the materials used were in some cases expensive and are discussed in more detail.

2.1 Microstrip patch

The microstrip patch element investigated was a disc patch constructed on a PTFE dielectric circuit board. The element consisted of a circular patch with two tuning stubs and a short circuit pin in the centre. It was fed at a point 45° to one of the stubs; a typical element is shown in Fig. 1. The structure is analysed in Ref. 3 but a summary of its operation is as follows; two spatially orthogonal modes of equal amplitude are excited on the patch, one in line with the tuning stubs and the other across the stubs. The tuning stubs are adjusted to obtain a 90° phase shift between the modes. This results in circularly-polarised radiation, which can be considered to be the sum of two equal-amplitude, linearly-polarised waves orthogonal in time and space.

The bandwidth of this element is expected to be low for a number of reasons. As the ground plane spacing of the patch is increased the radiation efficiency of the patch increases; this lowers the Q of the resonator and hence increases its bandwidth. However the efficiency of radiation from the feed line is also increased and a large ground plane spacing allows surface waves to be excited. Therefore the bandwidth of a microstrip patch is limited to a few percent. In this case the axial-ratio bandwith of the patch degrades at frequencies away from the design frequency and this also limits the bandwidth.

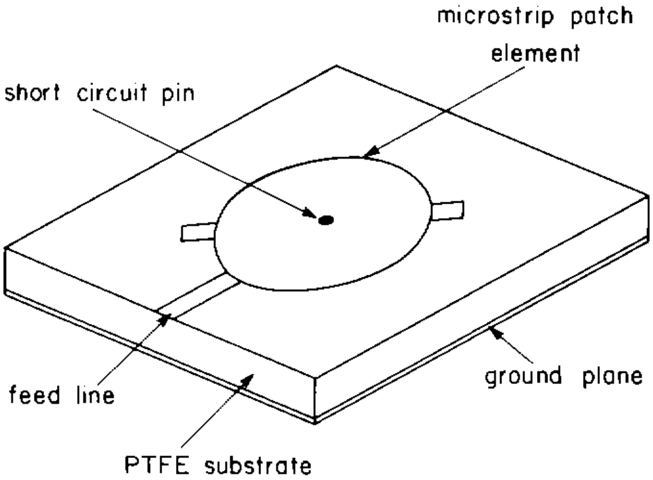


Fig. 1 - Microstrip patch element.

The radiation pattern of a single element was measured. The results show, Fig. 2, that an axial ratio of only 4 dB was achieved on broadside and considerable asymmetry was observed. This result is worse than that quoted in Ref. 3. In both cases, the axial ratio at 50° from broadside was poor and significant loss of gain at large angles had occurred. Both these factors make the element unsuitable for this application. The bandwidth of the element was found to be low, as expected.

A 4 by 4 element broadside array of these elements was constructed and measured. The radiation pattern, Fig. 3, shows that the mainbeam axial ratio has been improved; however, spurious radiation at angles away from broadside was evident. The spurious radiation, which is predominantly of one linear polarisation, is thought to be due to radiation from the microstrip feed network and is likely to become an increasing problem as the array size and hence the feed network length increases.

The advantages and disadvantages of the microstrip patch element can be summarised. It is a small, mechanically simple, circularly-polarised antenna element capable of working over a limited bandwidth. The disadvantages are, that its bandwidth is small, its radiation pattern is too directional and it has a poor axial ratio in the desired directions away from broadside. Spurious radiation from the microstrip feed network used by these elements is likely to be a problem that makes most types of microstrip patch used in conjunction with a microstrip corporate feed network unsuitable for use in a DBS flat-plate antenna.

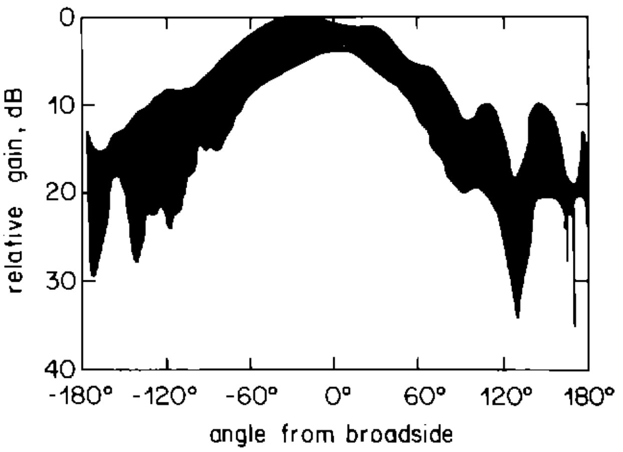


Fig. 2 - Radiation pattern of a single microstrip patch at 12 GHz. The range of levels shows the axial ratio at each angle.

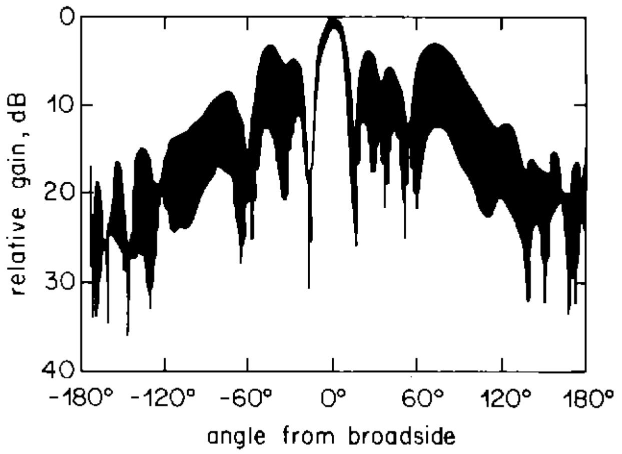


Fig. 3 - Radiation pattern of a 4 by 4 array of microstrip patches at 11.9 GHz. The range of levels shows the axial ratio at each angle.

2.2 Triplate slot

A slot element cut in the ground plane of a triplate structure was investigated. The fields on a slot cut in an infinite ground plane are the same as those on a complementary antenna, however the E and H fields are interchanged[4]. Therefore a narrow rectangular slot will have the same field distribution as a dipole of the same electrical length, resulting in a similar radiation pattern but of the other polarisation. The width of the slot will affect its bandwidth. The slot can be fed either by capacitive coupling or a direct connection from a triplate line passing under the slot. The former was selected as it removed the need for direct connections between different layers in the triplate structure, thus making it easier to construct. The disruption of the triplate fields in the vicinity of the slot can be modelled[5] as a series loading on the line. Therefore either a series or corporate feed network can be realised. A corporate feed was used and the feed line left open circuit a quarter of a wavelength beyond the slot. This transforms the series loading of the slot impedance to a parallel loading on the line. A sketch of the element used is shown in Fig. 4.

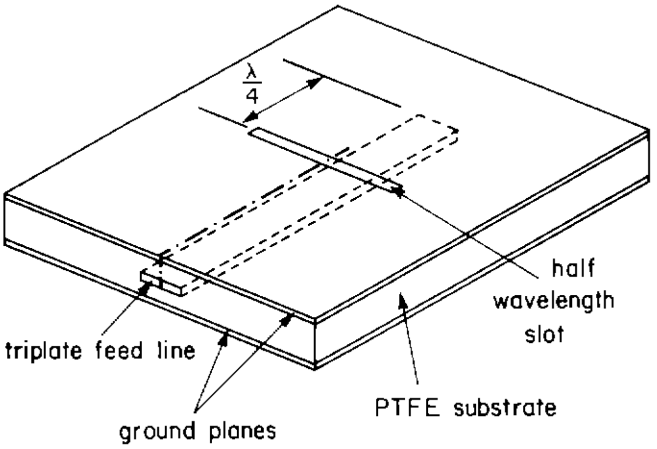


Fig. 4 - Triplate slot element.

The radiation pattern of a single element was measured in both the E and H planes. The results show, Fig. 5, the expected half-wave dipole pattern in the H plane and a less directional pattern in the E plane. Considerable radiation was found to occur from the edges of the ground plane and so it was necessary to connect the two ground planes, thus short-circuiting the energy in the mode. The presence of this energy was thought to be due to the imbalance in the triplate fields introduced by having a slot in only one of the ground planes.

The bandwidth of the slot was limited by the range of frequencies over which the input impedance could be matched. As has been mentioned the bandwidth is affected by the width of the slot. A bandwidth of around 8% was measured experimentally, which is sufficient for this application, however the exact value depended on a number of factors. The major ones were:

(a) the pressure and uniformity of pressure between the two halves of triplate structure;

and (b) the exact location of the short circuits between the ground planes.

These results showed that the details of the mechanical construction of the triplate structure can significantly affect the performance of the element.

A 2 by 2 element broadside array of slot elements was constructed and measured. The radiation pattern, Fig. 6, shows the expected pattern and also a good cross-polar discrimination. The input impedance match was measured and the voltage reflection coefficient was found to be below 25% over the full DBS band. To obtain these results considerable care was required in the mechanical construction.

The advantages and disadvantages of the slot element for this application can be summarised. It is a small, relatively simple, linearly-polarised element capable of operating over the desired bandwidth. Since it has a triplate feed structure there is little unwanted radiation from the feed lines. However, care was required to ensure a uniform construction and several short-circuit pins or other connections between the ground planes were required to control the unwanted modes. If this was not done the modes scattered off other elements and the edges of the array and caused considerable degradation of the radiation pattern.

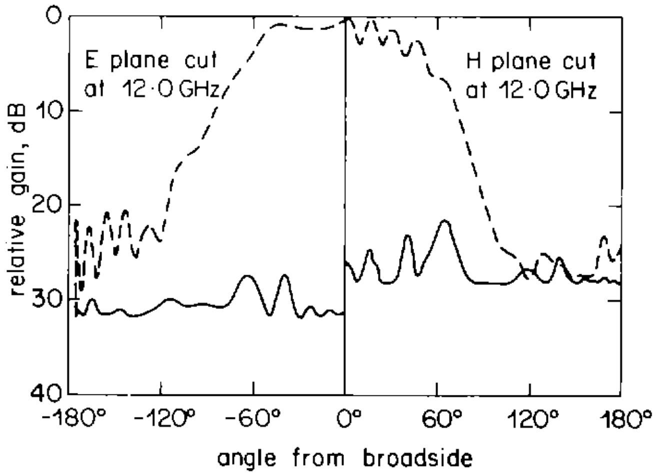


Fig. 5 - Radiation pattern of a single triplate slot.

– – – co-polar pattern
——— cross-polar pattern

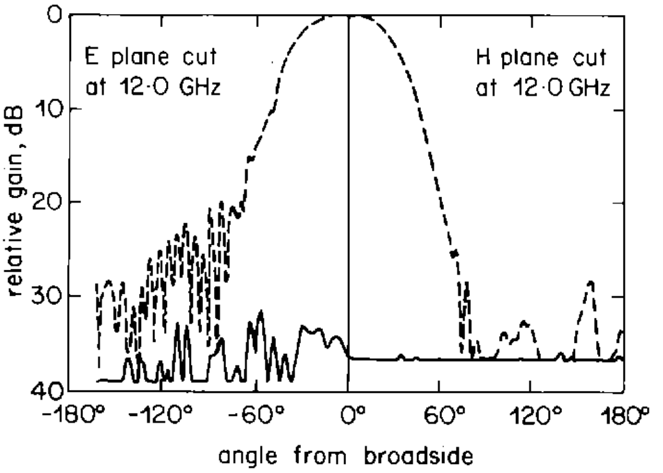


Fig. 6 - Radiation pattern of a 2 by 2 array of triplate slots (half wavelength spacing).

– – – co-polar pattern
——— cross-polar pattern

2.3 Folded-dipole patch

A folded-half-wave-dipole patch surrounded by a second ground plane was investigated. The element design, which was originally developed by Professor Dubost[6], consisted of a half-wave dipole with two folded arms. The element, Fig. 7, was backed and surrounded by a ground plane and was fed by capacitive coupling from a triplate line. The resulting element was a patch with an increased bandwidth due to the presence of the folded arms. In addition, the element was incorporated in a triplate structure so that an enclosed feed line could be used.

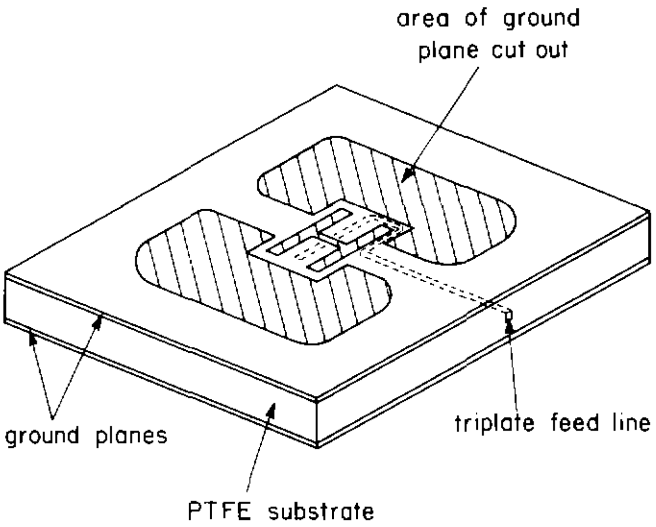


Fig. 7 - Folded-dipole patch element.

The current and field distributions on the element are those that would be expected on a folded dipole. However more detailed analysis is required to allow for the printed nature of the element. The element can be considered[6] as a number of lossless microstrip transmission lines; this analysis yields the resonance condition and allows calculation of the co-polar radiation pattern. An alternative method is to use a computer modelling program[7]. In both these cases the loading introduced on the triplate line by the element is unknown.

A folded-dipole element based on the design given in Ref. 6 was constructed and measured. The radiation patterns, Fig. 8, were found to give good agreement with the co-polar results reported by Dubost. In each case a cross-polar discrimination of at least 20 dB was achieved. The input impedance match was found to give a voltage reflection coefficient of less than 20% over a 7.5% bandwidth. It was also noticed that the amount of spurious radiation from the unwanted modes was considerably less than with the slot element. This was thought to be because the energy excited in unwanted modes propagated to the edge of the patch where it was radiated and so only caused a small change in the excitation of the patch.

A 2 by 2 element broadside array of folded-dipole patch elements was constructed and measured. The radiation pattern, Fig. 9, shows reasonably good agreement with the theoretical patterns. The only exception was the high sidelobe level measured in the E plane; this was thought to be due to imperfect power division in the feed network. Again a cross-polar discrimination in excess of 20 dB and a 7.5% bandwidth were observed.

To summarise, the folded-dipole element is a linearly-polarised element with a suitable radiation pattern and the desired bandwidth. The triplate feed reduces the problems caused by feed radiation and the element design reduces the excitation and propagation of unwanted modes. However, the element is relatively large and, like all those that have been discussed so far, constructed on a PTFE substrate — which is very expensive.

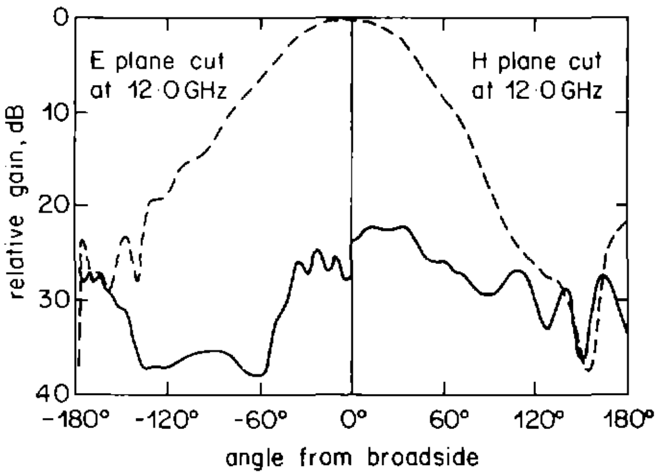


Fig. 8 - Radiation pattern of a folded-dipole patch.

--- co-polar pattern
—— cross-polar pattern

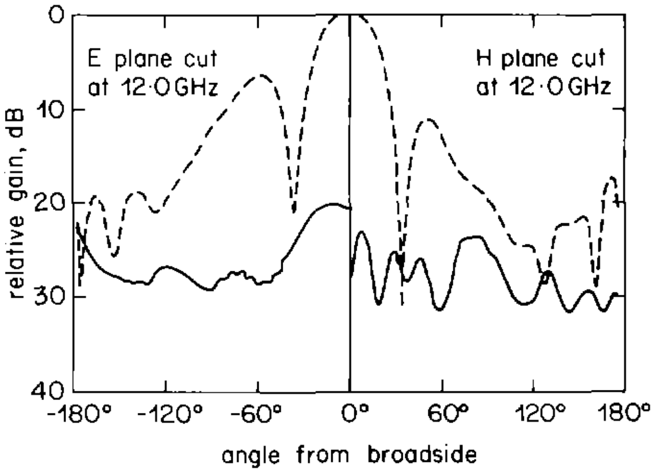


Fig. 9 - Radiation pattern of a 2 by 2 array of folded-dipole patches (spacing 0.9 wavelengths).

--- co-polar pattern
—— cross-polar pattern

2.4 Comb-line sub-array

A comb-line sub-array was investigated. The sub-array, which was developed by the Royal Military College of Science at Shrivenham[8] and investigated for use in a DBS flat-plate antenna under a BBC contract, consisted of a series feed to a number of quarter-wavelength long stubs. The stubs were placed on alternate sides of the line at regular interval. This arrangement resulted in a beam which was slewed in the direction of the feed to the sub-array. The slew angle was chosen by suitable design of the stub spacing. The aperture distribution across the sub-array was controlled by choosing the correct width of stub to couple the desired percentage of power out of the line. At the end of the line the remaining power was absorbed in a matched load. This prevented reflections which would radiate at the symmetrical slew angle, however it also reduced the efficiency of the sub-array. The sub-array structure is shown in Fig. 10.

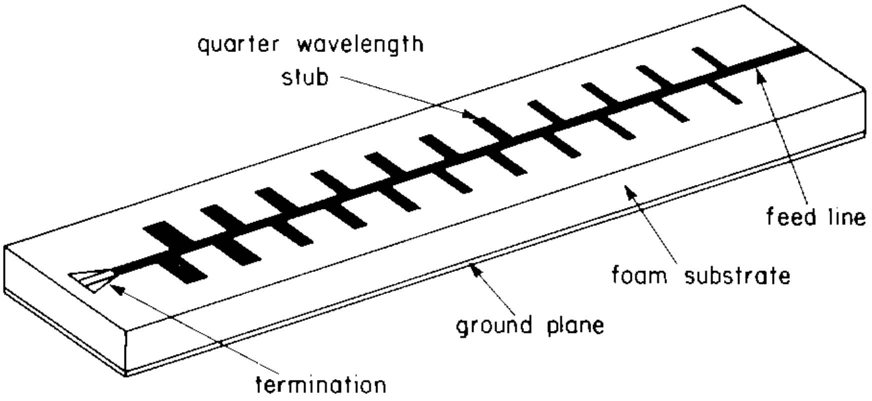


Fig. 10 - Comb-line sub-array.

The PTFE substrate material was replaced by a low-loss microwave foam. The foam has a relative permittivity close to unity which improved the radiation efficiency of the stubs. The foam was also considerably cheaper than PTFE. The copper sub-array structure cannot easily be deposited onto the foam so the structure was etched on copper attached to a thin sheet of polyimide film. The copper-covered film was then attached to the foam using ordinary adhesive. The result was a simple, fairly low-cost structure.

A sub-array was constructed and measured. The radiation pattern in the H plane showed the designed slew angle of 27° and a cross-polar discrimination of 20 dB, see Fig. 11. The problem associated with the sub-array was that the slew angle changed with frequency of operation. This resulted in a loss of array gain due to mispointing. This is known as 'scanning loss'. If the sub-array is made longer it exhibits a greater gain and the mainbeam in that plane becomes narrower; but because of the change in slew angle with frequency there is, for a given scanning loss, a narrower range of frequencies over which the array operates. The bandwidth of the sub-array is therefore limited by the amount of scanning loss that can be accepted. The input impedance presented a good match to the feed with a voltage reflection coefficient of less than 25% over a 17% bandwidth; a good input impedance match over a wide range of frequencies is however expected from arrays with this type of feed structure.

An array of three sub-arrays was also measured. The radiation pattern in the E plane is shown in Fig. 12. The H-plane pattern was, of course, similar to that shown in Fig. 11.

The comb-line sub-array is a linearly-polarised structure which is simple and relatively cheap to produce. It produces little feed radiation and a reasonably satisfactory radiation pattern. However, the bandwidth and maximum achievable gain of the array are limited because of scanning loss. Also the slewed main beam is not desirable as it is more compatible with the cartesian method of beam steering rather than the polar method which has been proposed[2] for a flat-plate antenna for DBS reception.

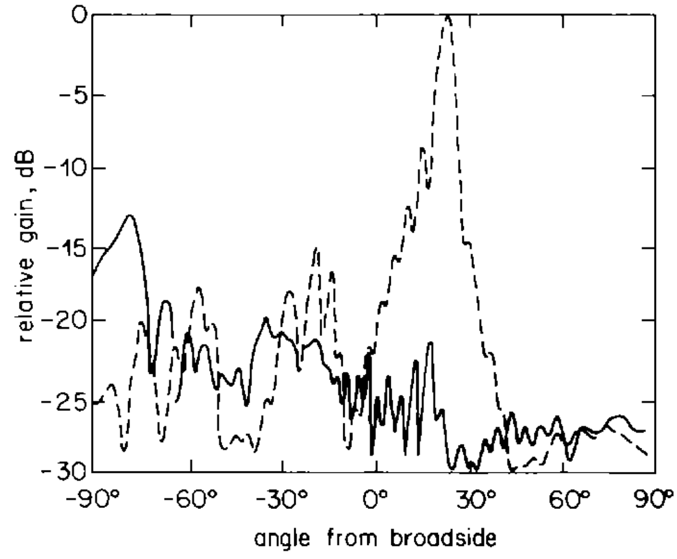


Fig. 11 - Radiation pattern of a comb-line sub-array in the H plane at 11.9 GHz.

— — — co-polar pattern
——— cross-polar pattern

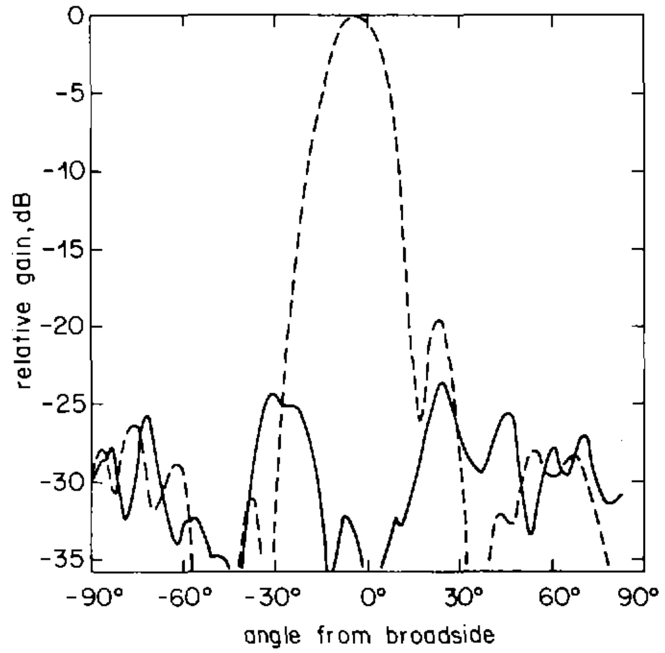


Fig. 12 - Radiation pattern of three comb-line sub-arrays in the E plane at 11.7 MHz.

— — — co-polar pattern
——— cross-polar pattern

2.5 Folded dipole with parasitic sub-elements

A folded dipole with closely spaced parasitic sub-elements was investigated[9]. The element consisted of a folded dipole which was fed by a balanced parallel-wire transmission line. A number of parasitic sub-elements on one side of the dipole were used to slew the radiation pattern of the element to the desired angle. The parasitic sub-elements were very closely spaced to each other and the dipole so that the whole element was physically narrow and similar elements could be packed together at the required spacing. The element was modelled using a computer and then scaled to operate at 11.9 GHz.

A wire-grid modelling program was used to design the element. The drive point impedance of the antenna was found and the currents on each wire were used to predict the far-field radiation pattern. Initial measurements indicated that parasitic sub-elements spaced very close to the folded dipole operated less well as 'reflectors' than as 'directors'. Therefore only 'directors' were considered in this investigation.

The number, length and spacing of the parasitic sub-elements were varied while keeping the geometry of the folded-dipole element unchanged. It was found that the directionality of the overall element improved when more parasitic sub-elements were introduced. As the sub-elements were spaced further apart the directionality also increased. A narrow element was required and so the number and spacing of the sub-elements was limited and an optimum of five sub-elements, each spaced 0.02 wavelengths apart, was found.

The element, Fig. 13, was scaled to operate at 11.9 GHz. A short length of 400 ohms line was used to match the element to the 200 ohms balanced feed line. The ground plane was spaced 1.6 mm below the element using microwave foam. The radiation patterns in the E and H planes were measured, Fig. 14, and these show the desired patterns and a reasonable cross-polar discrimination. The input impedance showed a good match over a 5% bandwidth.

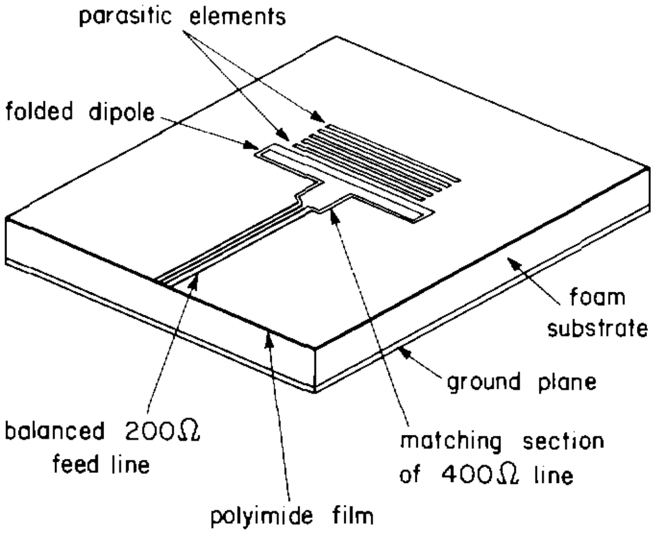


Fig. 13 - Folded dipole with parasitic elements.

Next, the performance of individual elements when placed in a small array was examined. As it was desired to slew the beam of the final array in the H plane, the performance of the element in this plane was of primary interest. Two effects were considered; mutual coupling between elements and distortion of the element radiation pattern which could be caused by the presence of other elements.

The radiation pattern of an element located in the middle of a linear array of eight elements is shown in Fig. 15. The elements were arranged with an offset between alternate rows to increase the element separation. The elements were found to suffer serious distortion of the radiation pattern when arranged in arrays. This was because the sub-elements rely totally on coupling from nearby radiators for their excitation and so nearby elements can significantly modify the radiation pattern of an element. The effect is probably exacerbated by the supergain exhibited by the element — where supergain is present a small change in the current distribution results in a large change in the radiation pattern.

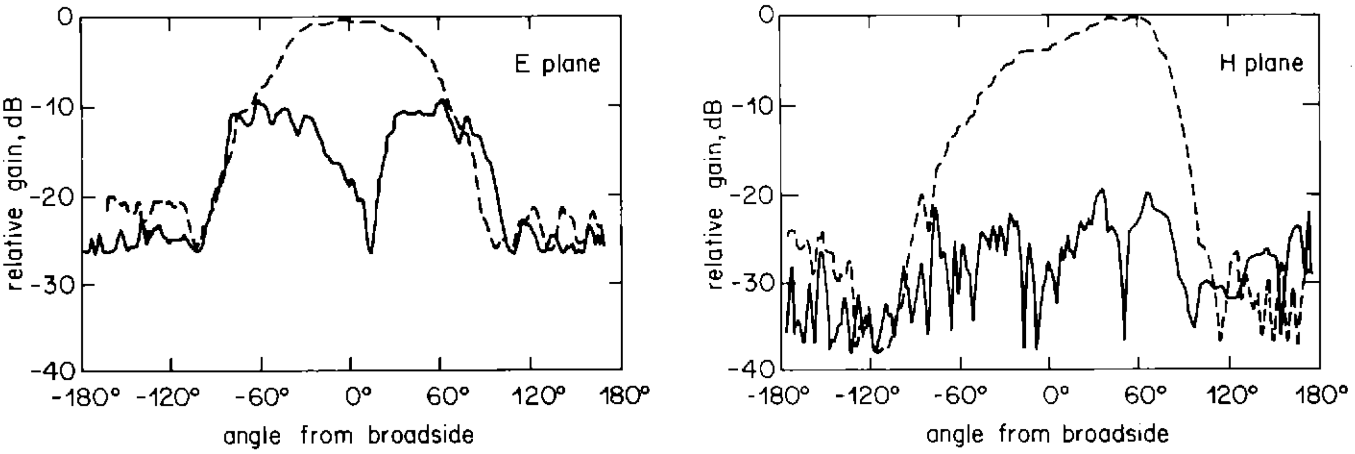
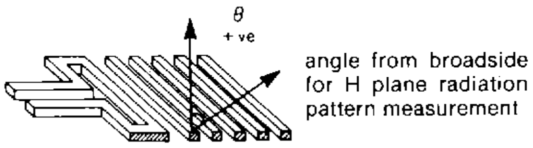


Fig. 14 - Radiation pattern of a folded dipole with five parasitic elements at 11.9 GHz in the E and H planes.

– – – co-polar pattern
——— cross-polar pattern



angle from broadside for H plane radiation pattern measurement

The mutual coupling was measured between adjacent elements in the offset 8-element array. At 11.7 GHz and 12.1 GHz the average coupling between the elements was found to be −23 dB and −22 dB respectively.

The advantages and disadvantages of the folded dipole with parasitic sub-elements can be summarised as follows. The element is a small, linearly-polarised element with the desired bandwidth and radiation pattern. However, when placed in an array the radiation pattern of the individual elements is distorted by the proximity of other elements; this could probably be allowed for by suitable modelling. The balanced feed structure was found to have a high loss and so only a short length of balanced feed line could be used to each element. This precludes the use of a balanced feed structure and so increases the complexity of the antenna.

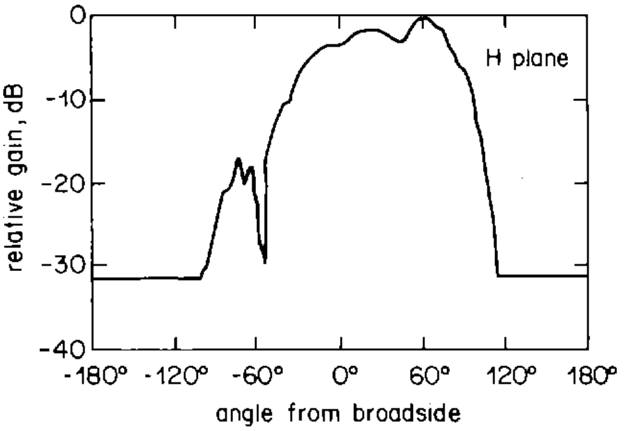


Fig. 15 - Radiation pattern of a folded dipole with parasitic elements in the middle of an 8-element linear array at 11.9 GHz in the H plane.

3. DISCUSSION

The relative advantages and disadvantages of the various types of element can now be discussed and the most suitable element chosen for further investigation. All the elements considered showed at least the minimum required bandwidth, a reasonably controlled radiation pattern and reasonable gain. The bandwidths of the folded dipole with parasitic sub-elements and the microstrip patch were the smallest; the comb-line sub-array was also narrow-band but had been so designed to obtain maximum gain.

The imbalance between the modes on the microstrip patch element resulted in poor polarisation performance. This was particularly serious away from broadside and means that this element is not suitable for use in an antenna which will have a main beam slewed away from broadside. The same conclusion can be drawn for most circularly-polarised microstrip patch elements as the difference in directivity between the E- and H-plane patterns, which causes the poor polarisation performance at angles away from broadside, is likely to occur in each case. A significant amount of feed radiation was also observed which makes an element which uses a microstrip feed unsuitable.

The polarisation discrimination of the other elements was satisfactory; however the spurious modes in the triplate structure surrounding the slot element are undesirable as they degrade the co-polar radiation performance. The modes can be removed with a number of short-circuit pins around each slot, however large numbers of pins are undesirable for manufacturing purposes and so this element should be avoided.

The comb-line sub-array is attractive for use in an array which uses a cartesian method of beam steering. In such a case, the sub-array slew could be set to the required elevation slew and the sub-arrays steered to give the desired azimuth slew. However, in a polar beam steering arrangement the extra slew is undesirable. In addition, the sub-array length and hence gain is limited by the scanning loss and so a square array of the required gain could not be built. Therefore the comb-line sub-array was rejected for this application.

The folded-dipole patch element had the required bandwidth and radiation pattern, and also permitted the use of an enclosed feed. There were however two major disadvantages:

(a) it was too large for similar elements to be stacked with a half wavelength spacing — the required spacing in one direction;

and (b) it was constructed using expensive PTFE material which would not be suitable for an antenna for the domestic market.

Both these problems might be solved by suitably redesigning the antenna element.

The folded-dipole with parasitic sub-elements was suitable when measured on its own. However, when mounted in an array, two problems were found:

(a) the coupling from adjacent elements caused distortion to the radiation pattern;

and (b) the balanced feed lines were found to be lossy.

The first of these problems might be minimised by computer modelling and testing. The second problem is fundamental for the given materials and construction techniques. If this element were used the length of the balanced line to each element would have to be minimised, resulting in a large number of baluns and a complex antenna design. Therefore this element was not considered further.

4. FURTHER DEVELOPMENT OF THE FOLDED-DIPOLE PATCH ELEMENT

It was decided to investigate the folded-dipole patch element further with a view to minimising the problems associated with it, namely its large size and the use of expensive materials in its construction. In this work low-loss microwave foam was used as a substrate. Initially it was decided to scale the element to operate at a lower frequency as this would make the measurements easier to perform.

The element was scaled to be 20 times larger than had been used originally. The original feed arrangement relied on capacitive coupling from the triplate feed to the element; in the scaled version this was replaced by a direct connection. The element was found to be resonant around 800 MHz. This was a higher frequency than might have been originally expected of a 12 GHz element scaled down by 20 times. The discrepancy was due to the change in substrate material. The area of ground plane cut out around the element was reduced, thus reducing the overall element size. It was found that this reduced the bandwidth of the element slightly and modified the input impedance. However a satisfactory element design was found.

Using the element dimensions determined in the UHF design, the element was then rescaled to operate at 12 GHz. The modified design is shown in Fig. 16. The input impedance had been found to change slightly with ground plane spacing. There was some flexibility in the choice of this spacing, therefore a spacing to fit one of the standard thicknesses of substrate was chosen. An element was constructed and measured and it was found that there was considerable radiation from the 'slots' formed by the ground plane cut-out. In another design this radiating mechanism could be specifically excited, however in this work shorting pins were placed in the middle of each slot to remove the mode. The resulting radiation patterns are shown in Fig. 17. The input impedance match was also found to be satisfactory giving a bandwidth of around 7% at 12 GHz.

In the design of the final array it was decided[2] to allow each column of array elements to be fed by a

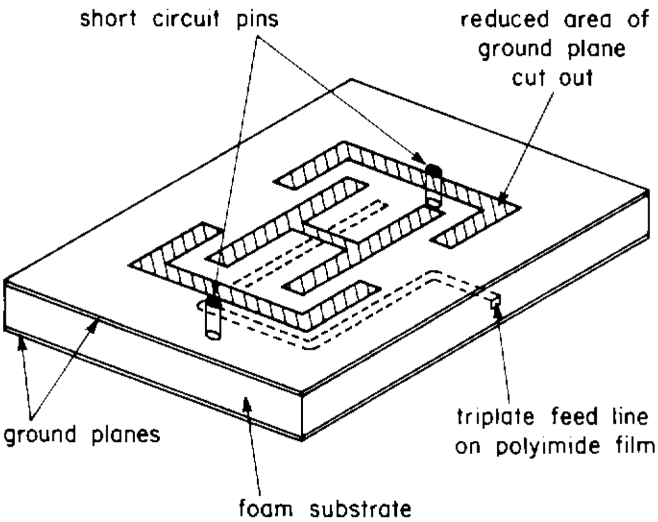

short circuit pins
reduced area of ground plane cut out
ground planes
triplate feed line on polyimide film
foam substrate

Fig. 16 - Modified folded-dipole patch element.

corporate feed network. A stacking arrangement of columns was then needed to maintain the desired element spacing, see Fig. 18. The effect of this stacking arrangement on the radiation pattern and input impedance of an individual element was then investigated. The new radiation pattern in the E and H planes is shown in Fig. 19; this shows that an asymmetrical H-plane radiation pattern is produced and that the cross-polar discrimination is not significantly reduced; the asymmetrical pattern is a fortunate additional advantage of this arrangement. The E-plane radiation pattern is degraded somewhat, however this effect is not serious as the array will be broadside in this plane. The bandwidth of the element was, as might be expected, somewhat reduced by this stacking arrangement. The mutual coupling between adjacent elements was measured and found to be around 25 dB; this reasonably low figure is probably due to the presence of the ground plane between the elements. The use of ground plane 'baffles' for minimising mutual coupling is well known but here it is implemented almost by accident.

The advantages and disadvantages of the modified folded-dipole element can now be summarised. The element is a small, linearly-polarised element which can be constructed from low-loss, low-cost materials. When mounted in the stacking arrangement proposed[2] it produces a slewed radiation

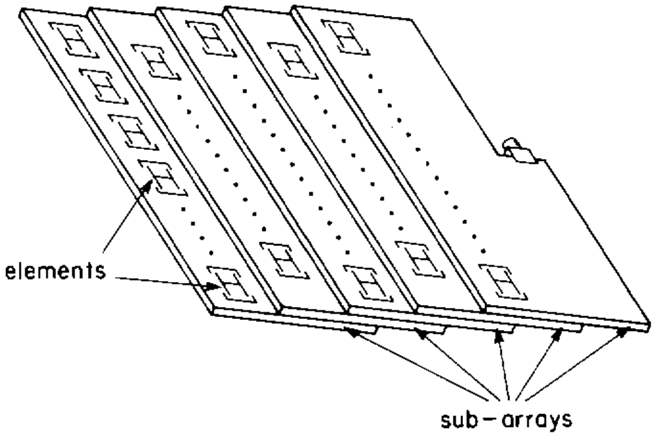


Fig. 18 - Stacking arrangement of sub-arrays.

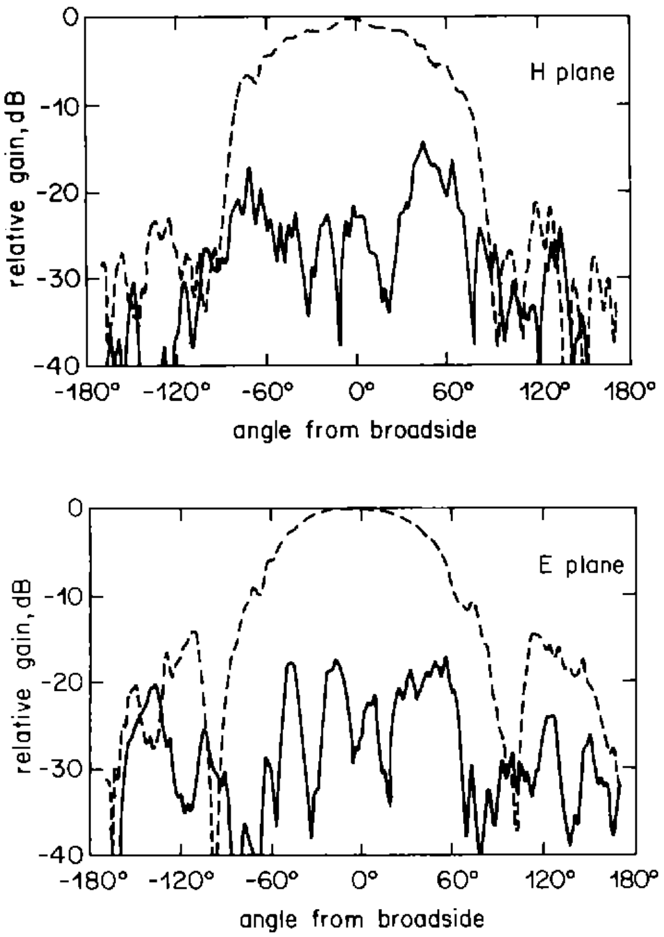


Fig. 17 - Radiation pattern of a modified folded-dipole patch element at 11.9 GHz.

– – – co-polar pattern
—— cross-polar pattern

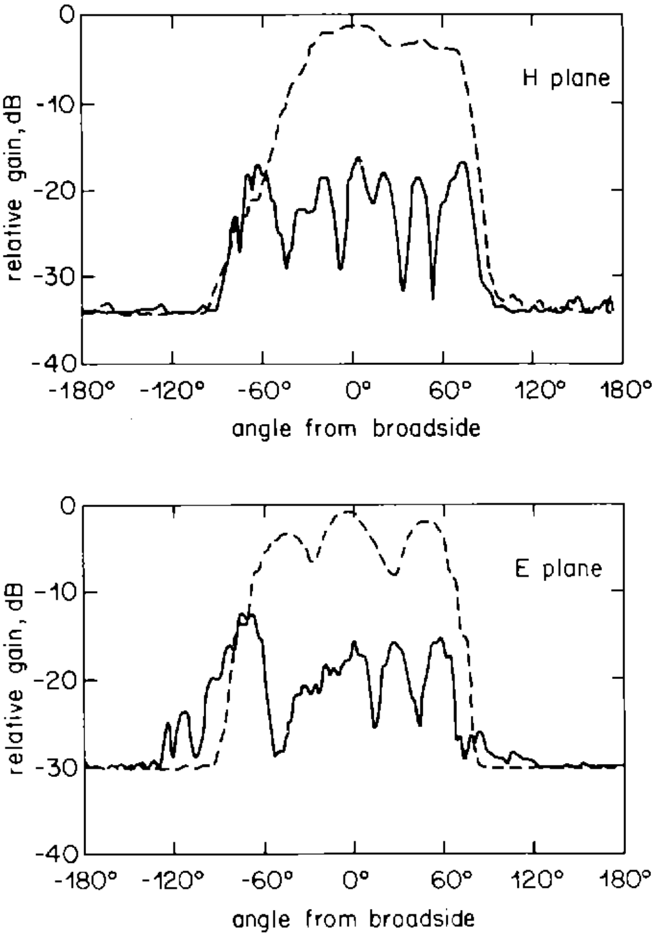


Fig. 19 - Radiation pattern of a stacked, modified, folded-dipole patch element at 11.9 GHz.

– – – co-polar pattern
—— cross-polar pattern

pattern over the desired bandwidth. However, it has been necessary to introduce two short-circuit pins which increase the mechanical complexity of the element. The slewed beam would not, of course, be produced if the stacking arrangement was not used.

5. CONCLUSIONS AND RECOMMENDATIONS

Various types of elements have been investigated and their advantages and disadvantages discussed. The following conclusions can be drawn:

(a) that low-cost materials such as a sandwich of very thin printed circuit material and a microwave foam substrate can and should be used,

(b) that two possible linearly-polarised element types have been identified which satisfy the requirements of radiation pattern, bandwidth, size and use of low-cost materials.

The individual element comprising a folded dipole with parasitic elements satisfies the requirements but its performance is degraded when other elements are placed in close proximity to it. The problem might be solved by the use of computer modelling and scaling techniques, but this would be time-consuming. The folded-dipole patch, when stacked as proposed in Ref. 2, satisfies the requirements and is suitable for use in a flat-plate array.

A suitable flat-plate antenna element for use in the flat-plate array proposed in Ref. 2 has been found and tested. It is recommended that this element, a folded-dipole patch, be used in the construction of a flat-plate antenna for DBS reception.

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7. REFERENCES

1. ITU. 1977. Final Acts of the World Administrative Radio Conference. Geneva 1977. Published by the International Telecommunications Union.

2. MADDOCKS, M.C.D. 1987. A Flat-Plate Antenna for DBS Reception. BBC Research Department Report No. BBC RD 1988/6.

3. HANEISHI, N., NAMBARA, T. and YOSHIDA, S. 1982. Study on Ellipticity Properties of Single-feed-type Circularly Polarised Microstrip Antennas. Electronics Letters, 4th March 1982, Vol. 18, No. 15. pp 191-193.

4. PAGE, H. 1963. An Introduction to the Theory of Aerials. BBC Research Department Report No. 1963/27. pp 80-83.

5. OLINER, A.A. 1954. The Radiation Conductance of a Series Slot in Strip Transmission Line. IRE Conv. Rec. 1954. Vol. 2, Part 8. pp 89-90.

6. DUBOST, G. and VINATIER, C. 1981. Reseau de Doublets Replies Symetriques en Plaque, a Large Bande autour de 12 GHz. L'Onde Electrique, April 1981, Vol. 61, No. 4. pp 34-41.

7. MOSIG, J.R. and GARDIOL, F.E. 1984. Polarisation State and Input Impedance of Arbitarily Shaped Microstrip Antennas. Proceedings of the 14th European Microwave Conference. pp 619-623.

8. HENDERSON, A., JAMES, J.R., HALL, P.S., STOTT, J.H. and BOARDMAN, D.H. 1985. Investigation of a Cost-constrained 12 GHz 'Flat-plate' Antenna for DBS. Proceeding of the 4th International Conference on Antennas and Propagation. April 1985. pp 108-112.

9. MADDOCKS, M.C.D. 1986. UK Patent Application No. 87-11270. 2nd June 1986.

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